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Lifestyle Interventions to Reduce Risk of Diabetes among Women with Prior Gestational Diabetes Mellitus

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Abstract

While lifestyle interventions involving exercise and a healthy diet in high-risk adults have been found to reduce progression to type 2 diabetes by more than 50%, little attention has been given to the potential benefits of such strategies in women with a history of gestational diabetes mellitus (GDM). We conducted a literature search of PubMed for English-language studies of randomized controlled trials of lifestyle interventions among women with a history of GDM. In total, 9 studies were identified which fulfilled the eligibility criteria. The majority of randomized trials of lifestyle interventions in women with GDM have been limited to pilot or feasibility studies. However, preliminary findings suggest that such interventions can improve diabetes risk factors in women with a history of GDM. Larger, well-designed controlled randomized trials are needed to assess the effects of lifestyle interventions on preventing subsequent progression to type 2 diabetes among women with GDM.

Keywords

Lifestyle intervention; Randomized controlled trial; Type 2 diabetes; Prevention; Diet; Physical activity; Postpartum; Pregnancy; Weight retention; Gestational diabetes mellitus

Background

Type 2 diabetes is a global epidemic. Worldwide, the total number of people with diabetes is projected to rise from 171 million in 2000 to 366 million in 2030 [1]. At the same time, the age at onset for type 2 diabetes is decreasing [2] highlighting the importance of identifying high-risk groups early, in order to implement prevention efforts. One such high-risk group is women who develop glucose intolerance during pregnancy. Both gestational diabetes mellitus (GDM) and milder glucose intolerance in pregnancy identify women who are at high risk for subsequent glucose intolerance and type 2 diabetes [3, 4].

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Gestational diabetes mellitus (GDM) is one of the most common complications of pregnancy with a prevalence rate varying from 1–20% depending on the population studied and diagnostic criteria applied [2, 5]. With the recent adoption of the International Association of Diabetes and Pregnancy Study Groups Consensus Panel (IADPSG) diagnostic criteria, it is estimated that 18% of pregnant women will be diagnosed with GDM [6]. Obesity is strongly associated with risk of GDM [7]. and it is expected that the incidence of GDM among women of reproductive age will further increase as the prevalence of obesity continues to rise among this age group.

GDM is related to short- and long-term adverse health outcomes for the mother. Compared with women with healthy pregnancies, women with histories of GDM have elevated CVD risk factors including higher blood pressure, triglyceride levels, and lower HDL [8]. Consistent with these findings, a meta-analysis found that GDM confers a 7-fold risk for future type 2 diabetes [9] and up to one third of women with type 2 diabetes have previously been diagnosed with GDM [10].

According to a systematic review, the highest risk period for the development of type 2 diabetes is within the first 5 years after a GDM pregnancy [3] with 50% of Hispanic women developing type 2 diabetes within 5 years [11]. Furthermore, a growing body of evidence shows a rapid postpartum change in in CVD risk factors [12]. For example, Retnakaran et al. found that by 12 months postpartum, 17.1% of those with recent GDM and 10% of women with milder degrees of gestational glucose intolerance had progressed to prediabetes or diabetes [13].

Therefore, pregnancy can unveil a preexisting susceptibility for type 2 diabetes and offers the opportunity to implement interventions to decrease such risk. However, while lifestyle interventions involving exercise and a healthy diet in high-risk adults have been found to reduce progression to type 2 diabetes by more than 50% [14–17], little attention has been given to the potential benefits of such strategies in women with a history of GDM. Indeed, studies of diabetes prevention among such high-risk pregnant and postpartum women are sparse. Collectively, the prior body of evidence suggests that such lifestyle interventions, if delivered to women with a history of GDM, would have the potential to delay or prevent one-sixth of type 2 diabetes cases in the female population [18].

Therefore, the goal of this review is to provide researchers and practitioners with a comprehensive overview of the randomized controlled trials of lifestyle interventions designed to reduce risk of diabetes or diabetes risk factors among women with a history of GDM. To this end, the review first describes the impact of the lifestyle interventions on incidence of type 2 diabetes and biomarkers of insulin resistance, weight change, and healthy behaviors such as physical activity, diet, and breastfeeding. The review then goes on to describe the study design and methods of new randomized trials which have been recently launched. The review concludes with a summary and recommendations for future research and practice.

Methods

We conducted a literature search of PubMed for English-language studies of randomized controlled trials of lifestyle interventions among women with a history of GDM. Only published peer-reviewed journal articles of original research in the English language were included. Keyword searches included: lifestyle intervention, randomized controlled trial, type 2 diabetes; prevention, diet, physical activity, postpartum, pregnancy, weight retention, gestational diabetes mellitus, and health behaviors. Additional relevant articles cited in the reference lists of identified papers were retrieved manually.

In total, 9 randomized controlled trials of lifestyle interventions conducted among women with a history of GDM were identified to fulfill the eligibility criteria (Table 1, Table 2) [19–25].

Of these studies, two examined the impact of the lifestyle intervention on subsequent incidence of diabetes [24, 26]. and four examined the impact on postpartum biomarkers of insulin resistance [21–23, 27].

In terms of other risk factors for diabetes, all with the exception of one study [26] examined the impact of the lifestyle intervention on weight change and physical activity. Four of the trials examined the impact on diet [20, 21, 25, 27]. Only one study to date reported the impact on breastfeeding [20].

Impact on Risk of Type 2 Diabetes and Biomarkers of Insulin Resistance

Among the nine randomized controlled trials conducted among women with GDM, two evaluated the impact of a lifestyle intervention on subsequent incidence of diabetes [24, 26] and four examined the impact on postpartum biomarkers of insulin resistance (Table 2) [21–23, 27]. The most successful intervention to date in terms of impact on subsequent diabetes, was observed by the Diabetes Prevention Program (DPP) [14], a multi-center randomized trial of an intensive lifestyle intervention conducted among a population of adults who had elevated fasting and post-load plasma glucose concentrations. Goals of the lifestyle intervention were at least a 7% reduction in enrollment weight, a low-calorie, low-fat diet, and at least 150 minutes/week of moderate-intensity physical activity. In a subset of this population limited to women with a selfreported history of GDM (n=350/2190), Ratner et al. [24] found that the incidence of type 2 diabetes in those randomized to the lifestyle intervention was 7.4 per 100 person-years, compared with 15.2 per 100 person years in the placebo group, for a 53% reduction in incidence (p=0.002). However, this study involved an intensive intervention not easily administered in a clinical setting and was conducted an average of 12 years after GDM diagnosis such that intervening lifestyle factors and subsequent pregnancies may have modified findings. For example, women with early postpartum conversion to diabetes, and therefore at highest risk, were not eligible.

In the second trial to evaluate the impact of the intervention on subsequent diabetes, Wein et al. [26] randomized two hundred women with previous GDM and subsequent impaired glucose tolerance during the timer period of 1989–1991 to an intensive dietary intervention targeting healthy eating and regular exercise (i.e., 30 minutes for three times per week) or to

routine dietary advice. Follow-up continued for a median of 51 months. Women randomized to the dietary intervention had an annual incidence rate of type 2 diabetes of 6.1% as compared to 7.3% in the control arm, for an incident rate ratio of 0.83 (95% CI 0.47–1.48) which was not statistically significant. As with the study by Ratner et al., this trial was conducted years after GDM diagnosis and therefore faced the same limitations described above.

Of the four studies which evaluated the impact of the lifestyle intervention on biomarkers of insulin resistance [21–23, 27], two observed a statistically significant positive impact on blood glucose measures [21, 27]. For example, Hu et al. randomized 404 participants in the Tianjin Gestational Diabetes Mellitus Prevention Program (TGMPP) diagnosed with GDM from 2005 to 2009 to either a lifestyle intervention or a control group [21]. The goals of the intervention included weight loss of 5–10% of pregnancy weight if overweight through reduction of at least 10% of total calories, participation in 150 minutes per week of moderate-intensity activity or harder, and reduction of total fat to less than 30% of calories. Interim one-year results indicate that women in the intervention group, had a greater reduction in plasma insulin levels (−11.8±27.4 pmol/l) as compared to those in the control arm (−3.2±31.2 pmol/l, p=0.004). The authors also observed the suggestion of a positive impact of the intervention on fasting glucose levels.

Similar findings were observed by Shyam et al. who randomized 77 Asian women who had been diagnosed with GDM in the prior two months to a low glycemic index dietary intervention or to a usual care control [27]. Goals of the intervention were a 5–7% reduction in body weight if prepregnancy BMI was greater than 23 kg/m^2, and moderate intensity physical activity of 30 minutes at least five times per week. At six months of follow up the intervention group had significantly greater decreases in 2-h post-load blood glucose after 75 g oral glucose tolerance test (median [IQR]: −0.2 [2.8] mmol/l) as compared to the control arm (0.8 [2.0] mmol/l), P=0.025). The suggestion of a beneficial impact on plasma insulin was not statistically significant.

Impact on Weight

With the exception of one study [26], all of the intervention studies conducted among women with prior GDM examined the impact on weight (Table 2). It is important to note here that four of these studies [21–23, 27] were conducted among women with current GDM or very recent (e.g., within the past 2 months) GDM, and therefore, were focused on postpartum weight loss and return to pre-pregnancy weight. The majority observed a statistically significant positive impact of the intervention [21, 24, 25, 27].

In a feasibility study, Ferrara et al. randomized women with a current diagnosis of GDM in late pregnancy to a lifestyle intervention which continued for 12 months postpartum or to a usual care control arm [20]. Goals of the intervention were to return to prepregnancy weight, if it was normal, or achieve a 5% reduction from prepregnancy weight if overweight. The proportion of women who reached the postpartum weight goal was higher, although not statistically significantly so, in the lifestyle intervention arm as compared to the usual care arm (37.5 vs. 21.4%, absolute difference 16.1%, p = 0.07). However, in the subgroup of

women not exceeding gestational weight gain guidelines, the lifestyle intervention was more effective (difference in the proportion of women meeting the weight goals: 22.5%, P=0.04).

Findings of similar magnitude were observed by Hu et al. in the Tianjin Gestational Diabetes Mellitus Prevention Program (TGDMDPP) [21]. Specifically, the authors found a 1.4 kg (2.1%) weight loss in the intervention arm at 1 year of follow-up compared to a 0.21 kg (0.3%) weight loss in the control arm (p=0.001), as well as a positive impact on BMI, body fat, and waist circumference. Ratner et al. in the DPP observed a weight loss of −5.13±0.43kg in the lifestyle arm after 6 months which decreased to a weight loss of −1.6±0.80kg at year three of follow-up [24]. Shyam et al. found that 33% of women in the intervention arm achieved the pre-specified weight loss goal as compare to 8% in the control arm (p=0.01) [27].

Impact on Physical Activity

All of the trials, with the exception of one [26], examined the impact of a lifestyle intervention on physical activity among women diagnosed with GDM (Table 2). Of these, three [21, 24, 25] observed a statistically significant impact on one or more measures of activity, while the others tended to observe the suggestion of a beneficial effect. For example, Reinhardt et al. randomized 38 women in rural Australia following their diagnosis of GDM into an exercise intervention or a control arm [25]. At 6 months follow-up, the intervention group increased leisure physical activity compared to the control group by 11 minutes per day (95% CI: 1, 22); however changes in total physical activity levels were not statistically significantly different between groups.

Hu et al. in the Tianjin GDM PP observed a similar positive impact on leisure time physical activity, with a percent increase of 59.4% in the intervention arm as compared to a 26.9% increase (p<0.001) in the control arm, but no significant impact on walking [21]. Ratner et al. in the DPP observed an increase of approximately 1.5 hours per week in moderate intensity physical activity after 1 year, which diminished to an increase of less than 30 minutes of physical activity by year three [24].

Impact on Diet

Four of the trials examined the impact of the lifestyle intervention on diet [20, 21, 25, 27] and all observed a statistically significant beneficial impact on one or more dietary components. For example, in the pilot feasibility study by Ferrara et al., the authors observe a percent difference in mean change in fat of −3.55% between the lifestyle arm vs. the control arm (p=0.002) [20]. Hu et al. in the TGDMPP observed that the lifestyle arm had 77.1% percent decrease in energy from fat as compared to a 68.9% decrease in the control arm (p=0.064) [21]. Reinhardt et al. [25] in their 6 month pilot in Australian women observed a change in total fat between arms of −19 g/day (95% CI: −37, −1). A beneficial impact of the lifestyle intervention on fiber was observed by Hu et al. and Shyam et al.

Impact on Breastfeeding

Only one study to date examined the impact of the lifestyle intervention on breastfeeding among women with prior GDM [20]. Specifically, Ferrara et al. found that the difference in percent of women partially or exclusively breastfeeding between the intervention and control arms was 15% (p=0.09)

Newly Launched Randomized Trials of Lifestyle Interventions to Prevent Diabetes among Women with GDM

The following section provides an overview of the recently launched lifestyle intervention studies among women with GDM. Five trials are currently ongoing (Table 3) [28–30].

Berry et al. [28] are conducting a randomized controlled trial among 100 African American, non- Hispanic white, and bilingual Hispanic women between 22–36 weeks of pregnancy who are diagnosed with GDM in North Carolina. Women are randomized in late pregnancy (22–36 weeks gestation) to a 14-week lifestyle intervention including diet, physical activity or to a wait-listed control group. Follow-up will continue to 10 months postpartum. Primary outcomes will include fasting blood glucose and BMI from baseline to 10 months postpartum. Secondary maternal outcomes will include clinical, adiposity, health behaviors and self-efficacy outcomes.

Chasan-Taber et al. are conducting Estudio Parto (Project Aiming to Reduce Type twO diabetes), a randomized controlled trial in Western Massachusetts [29]. A total of 300 Hispanic prenatal care patients who screen positive for GDM at 24–28 weeks gestation are randomized to a culturally and linguistically modified, individually-tailored lifestyle intervention or to a health & wellness comparison control group. Follow-up will continue to 12 months postpartum. The intervention is delivered via three in-person sessions, telephone booster calls, and mailed materials. Targets of the intervention are: 1) postpartum weight reduction to prepregnancy weight if prepregnancy BMI was in the normal range, or a 5% reduction from prepregnancy weight if prepregnancy BMI was overweight/obese, 2) at least 150 min per week of moderateintensity physical activity, and 3) reduction in postpartum total caloric intake via reduced consumption of popular calorie dense foods, reduced portion size, modifications in ethnic recipes, and higher fruit and vegetable intake. Primary outcomes will include postpartum weight loss, biomarkers associated with insulin resistance, other cardiovascular risk factors, and the adoption and maintenance of healthy physical activity and dietary behaviors.

Ferrara et al. are conducting the Gestational Diabetes' Effects on Moms (GEM) study [30], a cluster randomized clinical trial of 44 medical facilities at Kaiser Permanente Northern California. A total of 2,320 women with a GDM diagnosis between March 2011 and March 2012 are randomized to either the intervention or usual care conditions. Follow-up will continue to 12 months postpartum. The intervention is a Diabetes Prevention Program-derived print/telephone lifestyle intervention. Primary outcomes will include the achievement of postpartum weight goals and total weight change. Secondary outcomes

include postpartum glycemia, blood pressure, depression, percent of calories from fat, total caloric intake and physical activity levels.

Infanti et al. [31] are conducting Croi MyAction, a two-group, parallel randomized controlled trial for women with prior GDM. A total of 54 women with a history of GDM and persistent post-partum glucose dysfunction are randomly assigned to an intervention group or to a control arm. Follow-up will continue to one year post-intervention. The lifestyle intervention is delivered via in-person sessions including one-on-one sessions, group exercise, and education programs. Primary outcomes include fasting plasma glucose levels on a 75g oral glucose tolerance test.

Shih et al. are conducting the Mothers After Gestational Diabetes in Australia Diabetes Prevention Program (MAGDA-DPP), a randomized controlled trial among 574 women with a diagnosis of GDM in their most recent pregnancy [32]. Women are randomized to 12-month diabetes prevention program or to a usual care control group. The intervention is delivered via in-person and group sessions, and telephone. Follow-up continues for 12 months. Primary outcomes include incidence of diabetes, and secondary outcomes include cardiovascular risk factors and psychosocial and quality of life factors.

Discussion

Postpartum lifestyle interventions are critical in light of recent findings from long-term follow-up studies that a significant proportion of women with GDM go on to develop type 2 diabetes, especially during the first decade after the index pregnancy [9]. With the growing rates of diabetes and obesity in U.S. women, evidence regarding the effectiveness of lifestyle modification for the prevention of diabetes in women with GDM is critical. Therefore, GDM offers an important opportunity for the development, testing, and implementation of clinical strategies for prevention of subsequent type 2 diabetes [33]. Such protocols can capitalize on the teachable moment of pregnancy [34] and empower women to make postpartum lifestyle changes.

To date, the majority of randomized controlled trials of lifestyle interventions in women with GDM designed to prevent type 2 diabetes have been limited to pilot or feasibility studies. However, preliminary findings suggest that such interventions can improve postpartum biomarkers of insulin resistance and other diabetes risk factors in women with a history of GDM. Specifically, the trials conducted to date have observed favorable impacts on fasting glucose, insulin, postpartum weight, leisure time physical activity, and intake of total fat, fiber, and glycemic load. Only one study to date examined the impact on breastfeeding, and found the suggestion of a beneficial impact [20].

Recommendations for Future Research

While evidence is rapidly accumulating that behavior in the postpartum period may be critical in the prevention of longer term progression towards diabetes, lifestyle changes can be difficult to implement in these critical years after delivery. Postpartum women may be faced with the pressures of caring for a new baby in addition to their existing household and caregiving responsibilities. Recent qualitative data shows that having young children is a

major barrier to an active lifestyle in the first 12 months postpartum [35]. Other qualitative and quantitative studies indicate a number of barriers to physical activity during postpartum, including physical discomfort, parenting duties, too tired, lack of time, not prioritizing their health over other competing responsibilities, and lack of spousal/partner support [7].

A second challenge to implementing behavior change in the postpartum period is the relatively low perceived risk of future diabetes among women with recent GDM. A review [36] of studies examined the risk perceptions and health behaviors of women with previous GDM. The authors found low risk perceptions for future type 2 diabetes and suboptimal levels of physical activity and fruit and vegetable intake. The majority of studies reveal a distinct knowledge-behavior gap among this population as well as a lack of knowledge regarding necessary lifestyle modifications [36].

Promising strategies to address these challenges can be found in recent studies which have found a number of enablers to postpartum lifestyle changes including social support [37]. Dasgupta et al. [38] conducted focus groups among women within five years of a GDM diagnosis. Participants stated that their participation in a diabetes prevention program would be enhanced by face-to-face interactions with professionals and peers, provision of childcare support, and inclusion of spouses/partners. Therefore, interventions which integrate the entire family and influence family members, along with the participant, to adopt health promoting behaviors may be particularly successful.

In this vein, and to address transportation barriers, home-based interventions conducted via mail, telephone, internet/e-mail, and text-messaging, or involving home visits by health educators may be more feasible and acceptable to women in the postpartum period. For example, several recent trials which relied largely on the internet, mail, or telephone have observed promising results }} Furthermore, there is evidence that internet-based lifestyle interventions can increase exercise in a general postpartum population [39]. However, at the same time internet access may be a barrier as women with GDM tend to have lower socioeconomic status than women without GDM [40].

Weight loss interventions which begin during pregnancy may be more effective than those initiated only in the postpartum period given the strong association between GWG and postpartum weight retention, and the fact that it may be difficult to reduce postpartum weight retention without first preventing excessive gestational weight gain during pregnancy [41]. Two of the published trials began in late pregnancy [20, 25] and suggest that such protocols can have a beneficial impact on gestational weight gain as well as prepare women for postpartum changes. Consideration should also be given to translating such programs to clinical care. In their newly launched study [30]. Ferrara et al. are evaluating whether delivering a diabetes prevention program at the health system level is able to successfully reach women with prior GDM.

Breast feeding has been associated with reduced blood glucose levels and a reduced incidence of type 2 diabetes among women with a history of GDM [42]. However, only one of the nine published trials included breast feeding as one of their goals [20]. Future trials should focus on promoting a combination of breast feeding, diet and physical activity.

Finally, rates of progression to type 2 diabetes vary by ethnicity, with, for example, Asian and Hispanic women having higher rates of progression than non-Hispanic white women [43]. At the same time, Hispanic women have higher rates of overweight/obesity when entering pregnancy and are more likely to be sedentary than non-Hispanic white women [43] Future studies should focus on these high risk groups. One newly launched study [29] is being conducted in Hispanic women only and will evaluate whether a culturally-modified intervention will be effective in reducing diabetes risk in Latinas with GDM.

Summary

Larger, well-designed controlled randomized trials are needed to assess the effects of lifestyle interventions on preventing subsequent progression to type 2 diabetes among women with GDM. Such interventions which focus on the acquisition of healthy lifestyle skills in late pregnancy and postpartum have a high potential for preventing the intergenerational cycle of diabetes in this high-risk population.

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Practice Points

- Preliminary findings suggest that lifestyle interventions can improve diabetes risk factors in women with a history of GDM.

Research Agenda

- Larger, well-designed controlled randomized trials are needed to assess the effects of lifestyle interventions on preventing subsequent progression to type 2 diabetes among women with GDM.

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Table 1

Randomized Trials of Lifestyle Interventions to Reduce Risk of Type 2 Diabetes among Women with Gestational Diabetes Mellitus (GDM); Study Designs.

Author (year)	Name	Design	Pilot	Population	Intervention	Mode	Goals
Cheung et al.; 2011		RCT; FU: 12 mos.	Pilot	43 women with previous GDM <4 yrs. previously; Australia	Exercise intervention vs. usual care control	individualized inperson; telephone; mailings	PA: 150 min/wk. or 10,000 steps/day for 5 days/wk.
Ferrara et al.; 2011	DEBI (Diet, Exercise and Breastfeeding Intervention)	RCT; FU: 12 mos.	Pilot	197 women with current GDM; California	Lifestyle intervention (diet, exercise, breastfeeding) vs. usual care control	individualized inperson; telephone	Weight: return to prepregnancy weight if normal, lose 5% of prepregnancy weight if overweight; PA: 150 min/wk. of moderate-intensity or harder; Diet: ≤25% calories from fat; Breastfeeding: exclusively for 6 mos.
Hu et al.; 2012	Tianjin Gestational Diabetes Mellitus Prevention Program (TGDMPP)	RCT; 1 yr.	Preliminary results	404 women with previous GDM from 05–09; China	Lifestyle intervention (diet and exercise) vs. usual care control	individualized in-person	Weight: no weight loss if normal weight, lose 5–10% of prepregnancy weight if BMI≥24kg/m^2 through reduction of ≥10% total calories; PA: 150 of moderate-intensity or harder; Diet: T <30%; fiber 20–30 g/day; % calories from fat
Kim et al.; 2012		RCT; FU: 13 wk.	Pilot	49 women with previous GDM within past 3 yrs.; Michigan	Exercise intervention vs. usual care control	web based	Steps: up to 10,000 steps/day
McIntyre et al.; 2012		RCT; FU: 12 wks.	Pilot	28 women with previous GDM 6 wks. postpartum; Australia	Exercise intervention vs. usual care control	individualized inperson; telephone	PA: 150 min/wk.
Ratner et al.; 2008	Diabetes Prevention Project (DPP)	RCT; FU: 2.8 yrs.		350 women with previous GDM and current elevated glucose levels from the DPP; US	Lifestyle intervention (diet and exercise) vs. placebo	individualized in person; group sessions	Weight: Reduction ≥7% of initial body weight; Diet: low-calorie, low-fat; PA: moderate intensity ≥150 min/wk.
Reinhardt et al.; 2012		RCT; FU: 6 mo.	Pilot	38 women following GDM diagnosis; Australia	Lifestyle intervention (diet and exercise) vs. usual care control	telephone; mailings	Healthy eating and physical activity
Shyam et al.; 2013		RCT; FU: 6 mos.		77 women with previous GDM within 2 mos.; Malaysia	Low GI diet vs. usual care control	in-person; text messaging, emails	Weight: 5–7% reduction in body weight if BMI>23 and maintain if normal; PA: moderate intensity 30 minutes/day for 5

Author (year)	Name	Design	Pilot	Population	Intervention	Mode	Goals
							times/wk.
Wein et al.; 1999		RCT; FU: 796 person-years (median 51 months)		200 women with previous GDM from 89–91 and subsequent IGT	Diet intervention vs. control	telephone; mailings	Diet: healthy eating; PA: exercise (30 minute for 3 times/wk.)

RCT = randomized clinical trial; FU = follow-up; GDM = gestational diabetes mellitus; IGT = impaired glucose tolerance; PA=physical activity; FG=fasting glucose; GI = glycemic index; PA = BMI = body mass index

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Table 2

Randomized Trials of Lifestyle Interventions to Reduce Risk of Type 2 Diabetes among Women with Gestational Diabetes Mellitus (GDM); Findings.

Author (year)	Name	Impact on Type 2 Diabetes	Impact on Biomarkers of Insulin Resistance	Impact on Weight	Impact on PA	Impact on Diet	Impact on Breastfeeding
Cheung et al.; 2011		NA	NA	BMI (kg/m^2): 28 (95% CI: 23.9, 34.3) vs. 25.5 (95% CI: 22.5, 28.7), p=0.14	Steps (% achieving goal): 30.8 vs. 17.6 p=0.34; PA (% achieving goal): 70.0 vs. 57.9, p=0.51	NA	
Ferrara et al.; 2011	DEBI (Diet, Exercise and Breastfeeding Intervention)	NA	NA	Weight (% achieving goal): 37.5% vs. 21.4%, p=0.07	PA (difference in mean change in min/wk.): 25.3, p=0.91	Fat (% difference in mean change) −3.6, p=0.002	Breastfeeding (difference in % partially or exclusively breastfeeding): 15%, p=0.09
Hu et al.; 2012	Tianjin Gestational Diabetes Mellitus Prevention Program (TGDMPP)	NA	FG (change in mmol/l): −0.09±.52 vs. −0.09±0.6, p=0.97; Insulin (change in pmol/l): −11.8±27.4 vs. −3.2±31.2, p=0.004	Weight change: −1.4±3.44 kg vs −0.21±3.52 kg (0.3%), p=0.001; BMI change: −0.50±1.41 kg/m^2 vs. −0.09±1.37 kg/m2, p=0.004	LTPA (% increased): 59.4% vs. 26.9%, p<0.001	Fat (% decrease): 77.1 vs. 68.9, p=0.064; Fiber (% increase) 59.5 vs. 47.4, p=0.012	NA
Kim et al.; 2012		NA	FG (change in mmol/l): −0.046 vs. 0.038, p=0.65; 2 hr. glucose on 75g OGTT (change in mmol/l): −0.48 vs. −0.42, p=0.91	Weight (change in kg): −0.14 kg vs. −1.5 kg, p=0.13	PA (% moderate-intensity): 58 vs. 47, p=0.51	NA	NA
McIntyre et al.; 2012		NA	FG (change in mmol/L): 0.25+.56 vs. 0.12+0.42, NS; Insulin (change in μU/mL): 1.49+4.23 vs. 0.06+3.89, NS	Change in weight (kg): 0.97+3.7 vs. 0.22+4.2 NS	PA (median [range] increase in planned PA mins./wk.): 60 (0–540) vs. 0 (0–580); p=0.234; walking: NS	NA	NA
Ratner et al.; 2008	Diabetes Prevention Project (DPP)	Diabetes: 53% risk reduction vs. placebo, p=0.002	NA	Weight (change in kg): −5.13±0.43 vs. approx. 0 in placebo at 6 mos.; −1.6±0.80 vs. approx. 0 in placebo at 3 yrs.	PA (change in h/wk.): 1.5 h/wk. vs. NA in yr. 1; <0.5 vs NA in yr. 3.	NA	NA
Reinhardt et al.; 2012		NA	NA	BMI (difference in change in kg/m2): −1.5 (95% CI: −2.8, −0.1); Weight (difference in change in kg): −4.0 (95% CI: −7.6, −0.5)	LTPA (change in min/day): 11 (95% CI: 1, 22)	Total fat (change in g/day): −19 (95%CI: −37, − 1); GL (unit change) −26 (95% CI −48, −4)	NA

Author (year)	Name	Impact on Type 2 Diabetes	Impact on Biomarkers of Insulin Resistance	Impact on Weight	Impact on PA	Impact on Diet	Impact on Breastfeeding
Shyam et al.; 2013		NA	Glucose: 2hr post 75g OGTT (median mmol/l, IQR): −0.2 (2.8) vs. 0.8 (2.0), p=0.025; Insulin (<2 μU/L): 61.5% vs. 52.6%, p=0.228	Weight (% achieving goal): 33% vs. 8%, p=0.01	PA (median METmin/ wk., IQR): 933 (1403) vs. 965 (857), p=0.908	Fat (g): 58±18 vs. 53±16, p=0.695 for difference in change; Fiber (g): 17±4 vs. 13±4, p=0.02 for difference in change; GI: 57±5 vs. 64±6, p=0.033 for difference in change	
Wein et al.; 1999		Diabetes (annual IR): 6.1% vs. 7.3% (IRR=0.83, 95% CI: 0.47, 1.48)	NA	NA	NA	NA	

RCT = randomized clinical trial; FU = follow-up; GDM= gestational diabetes mellitus; IGT= impaired glucose tolerance; PA=physical activity; FG=fasting glucose; GI = glycemic index; PA = physical activity,

Table 3

Newly Launched Randomized Trials of Lifestyle Interventions to Reduce Risk of Type 2 Diabetes among Women with Gestational Diabetes Mellitus (GDM)

Author (year)	Name	Design	Population	Intervention	Mode	Goals	Outcomes
Berry et al.; 2013		RCT; FU: 10 mos.	100 ethnically/ racially diverse women with current GDM; North Carolina	Lifestyle intervention (diet and exercise) vs. control	individualized in-person; group sessions; text messaging.	Healthy behaviors	Primary: FPG, BMI; Secondary: clinical, adiposity, behaviors, self efficacy
Chasan-Taber et al.; 2014	Estudio Parto	RCT; FU: 12 mos.	300 Hispanic women with current GDM; Massachusetts	Lifestyle intervention (diet and exercise) vs. health & wellness control	individualized in-person; telephone; mailings	Weight: return to prepregnancy weight if normal weight, lose 5% of prepregnancy weight if overweight; PA: 150 min/wk. of moderate-intensity or harder; Diet: <25% calories from fat	Primary: postpartum weight retention, biomarkers of insulin resistance and CVD; Secondary: exercise, diet
Ferrara et al.; 2014	Gestational Diabetes' Effects on Moms (GEM) study	RCT; FU 12 mos.	2,320 women with a GDM diagnosis between March 2011 and March 2012; California	Lifestyle (diet, exercise) vs. usual care control	telephone; mailings	Weight: return to prepregnancy weight if normal weight, lose 5% of prepregnancy weight if overweight or obese PA and Diet: individualized goals	Primary: postpartum weight; Secondary: postpartum glycemia, blood pressure, depression, % calories from fat, total caloric intake, PA levels.
Infanti et al.; 2013	Croi MyAction	RCT; FU: 12 mos.	54 women with previous GDM and persistent postpartum glucose dysfunction; Ireland	Lifestyle intervention (diet and exercise) vs. control	individualized in-person; group	Healthy lifestyle	Primary: FPG; Secondary: insulin resistance, diet adherence, weight and BMI, PA and fitness, lipid profile, psychological factors
Shih et al.; 2013	Mothers After Gestational Diabetes in Australia Diabetes Prevention Program (MAGDA-DPP)	RCT; FU: 12 mos.	574 women with GDM in most recent pregnancy; Australia	Lifestyle intervention (diet and exercise) vs. control	individualized in-person; group sessions; telephone	Weight: Reduce >5%; PA ≥30 min/day moderate-intensity; Diet: Fat intake <30%; fiber >15 g per 1000 kcal	Primary: diabetes risk; Secondary: psychosocial, QOL, CVD risk factors

RCT = randomized clinical trial; FU = follow-up; GDM = gestational diabetes mellitus; IGT = impaired glucose tolerance; PA=physical activity; FG=fasting glucose; GI = BMI = body mass index; kcal = kilocalories; QOL = quality of life; CVD = cardiovascular disease